N89-15040

A SYSTEM FOR CONDUCTING IGNEOUS PETROLOGY EXPERIMENTS UNDER CONTROLLED REDOX CONDITIONS IN REDUCED GRAVITY

Williams, R. J., SN12, NASA-JSC, Houston, TX 77058

The Space Shuttle and the planned Space Station will permit experimentation under conditions of reduced gravitational acceleration offering experimental petrologists the opportunity, as never before to study crystal growth, element distribution, and phase chemistry under entirely new conditions. In particular, the confounding effects of macro- and micro-scale buoyancy-induced convection and crystal settling or floatation can be greatly reduced over those observed in experiments in the terrestrial laboratory. Also, for experiments in which detailed replication of the environment is important, the access to reduced gravity will permit a more complete simulation of processes that may have occurred on asteroids or in free-space. This latter aspect may be particularly relevant to studies of petrogenesis of chondrules and other meteorite components.

Most of the geologically interesting systems contain significant amounts of redox-sensitive ions--Fe, Ti, Cr, etc.--and, thus, studies of phase relations and crystallization require control of the oxygen fugacity during the experiment. Sophisticated, but rather standardized techniques, have been developed to control, measure, and manipulate oxygen fugacity in the terrestrial laboratory. Gas mixing is the major technique used in the study of one atmosphere igneous processes; unfortunately, it is not directly adaptable to use in space experimentation, because large quantities of gas must be flowed over the sample to maintain the oxygen fugacity. It is the purpose of this paper to describe a newly developed technique that can be used to control, measure, and manipulate oxygen

fugacities with small quantities of gas which are recirculated over the sample. This system could be adaptable to reduced gravity space experiments requiring redox control.

System Description

The system employs a single solid ceramic oxygen electrolyte cell for both control and measurement of the oxygen fugacity. This is possible because the electrolyte cells can be used as oxygen pumps to adjust the CO_2/CO ratio in the gases that are used to impose redox control in gas mixing systems electronically.

The system consists of a furnace surrounding a closed-end alumina muffle which surrounds a closed-end oxygen electrolyte tube that is platinized on both sides. A sample is suspended inside the electrolyte tube. Seals separate the gas in the alumina tube from the inner side of the electrolyte tube and isolate both from the laboratory atmosphere. Electrical feed-throughs connect the inner and outer electrode contacts to a DC power supply. The space between the aluminum muffle and the electrolyte cell is filled with oxygen gas (1 atmosphere pressure at 1200°C) and sealed. The inner side of the electrolyte cell is filled with a 1:1 mixture of CO and CO_2 (also at 1 atmosphere at 1200°C). This mixture is sealed off and recirculated within the inner cell by a small pump.

The oxygen fugacity is manipulated by applying a voltage to the cell and transferring oxygen in to or out of the interior volume depending on the experimental condition desired. The oxygen fugacity can be cycled between those of the quartz-fayalite-magnetite and quartz-fayalite-iron buffers in about 30 minutes at 1200°C, maintained to within 0.05 log units of a preset value over day-long periods, or changer in a controlled manner as function of temperature so that a

preselected pattern is replicated during cooling or heating. The oxygen fugacity is measured by turning off the electrolysis voltage and recording the EMF with a high impedance DC millivolt meter.

A high efficiency (approximately 0.2 watts/^{o}C) furnace has been specially designed to operate on 28 VDC. At 1200^{o}C, the hot zone is 2 inches long, by 2 inches diameter. The power supply to the furnace is controlled using a standard thermocouple as a sensor. It will maintain the temperature to within less than 1^{o}C of a preselected temperature and can cool the system at controlled rates between 0.5^{o} to 100^{o}C per hour; heating rates of up to 1000^{o}C/hr are possible. The maximum operating temperature is 1350^{o}C for the current furnace.

A micro-computer is used to control both temperature and oxygen fugacity, both of which can be changed independently as a function of time. The computer also performs data acquisition tasks, and switches between the measurement and oxygen pumping modes of operation.

Experiments done conventionally and those done using this system yield identical results in a one-g gravity field.

The total system (exclusive of the computer use for laboratory control) is 4 cubic feet; it uses about 500 watts. Except for the gas used to charge the system (approximately 30 cc at STP), no gas is used during the experiment. Although water cooling is now used to control the temperature of the furnace seals, radiative cooling is probably possible.

Summary

A system directly adaptable for use in controlled oxygen fugacity experimentation on Shuttle or Space Station has been

designed, built, and tested. It should permit reduced gravity experiments which require such control to be undertaken.